THE AFFECTS OF HIGH TEMPERATURE STEPS ON BOW, WARP AND SLIP OF A WAFER

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ABSTRACT

Bow, Warp and Slip measurements were used to characterize push/pull rates of a three inch oxidation furnace. The push/pull rates were varied from 3 to 30 inches per minute. To minimize the amount of bow, warp, and slip while still being time efficient, recommended push rates of 12 and pull rates of 3 in/min should were found.

THEORY

In Integrated-Circuit fabrication, a wafer usually sees many processing steps involving heat, some of which may create stresses that are not beneficial. Physical stresses occur during the heating and cooling of the wafers because of the temperature gradients along the wafer. One of the variables involved in controlling the stresses due to heating and cooling is the push/pull rates for the furnace. Typical stacking arrangements for an oxide furnace usually involve 50 wafers spaced about 0.5cm apart. Inside the furnace, the hot ambient circulates around the wafers as a whole and usually a stagnant layer evolves in between the wafers. This leads to the wafers being heated from the outside in. The cooling process is similar. Because the edges have more surface area involved, the heating/cooling process is accelerated even more. These temperature gradients across the wafer result in physical stresses.

One defect that can result is called slip. Slip occurs when the stresses involved in the wafer cause the actual crystal lattice to dislocate. This starts when one crystal plane severs. This dislocation then causes another plane to dislocate. The original and second dislocation lines then combine to form a new crystal plane. As these dislocations continue throughout the entire wafer, slip is said to occur [1,2]. When slip has run its course, there is one incomplete plane of atoms on the top surface of the wafer and one incomplete plane on the bottom. This is illustrated in Figure 1. To highlight the slip defect, a decoration etch needs to be performed. This etch is made of a mixture of chromic and hydrofluoric acid. Slip may be seen visually, but to be sure, an optical microscope should be used.

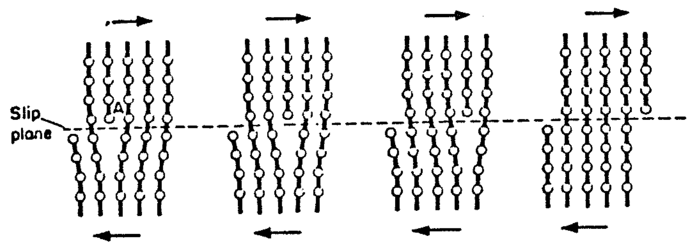

Figure 1: Slip Progression

Warp and bow are measurements which take into account the concave and convex nature of a wafer. To determine warp and bow of a wafer, the physical curvature of the wafer must be determined [3]. Figure 2 contains the ASTM standard method of measuring warp. Warp is determined by finding the difference between the relative maximum and minimum heights of the wafer. Bow is measured in the same way except that the edge and center points are used instead of the max and min points. As can be seen, bow and warp measurements take into consideration the Total Thickness Variation (TTV) across the wafer. If the measurement system cannot measure both surfaces, only the curvature of one surface can be used and the assumption that the TTV of the wafer is zero must be made. Figure 3 shows how bow and warp are measured using these conditions.

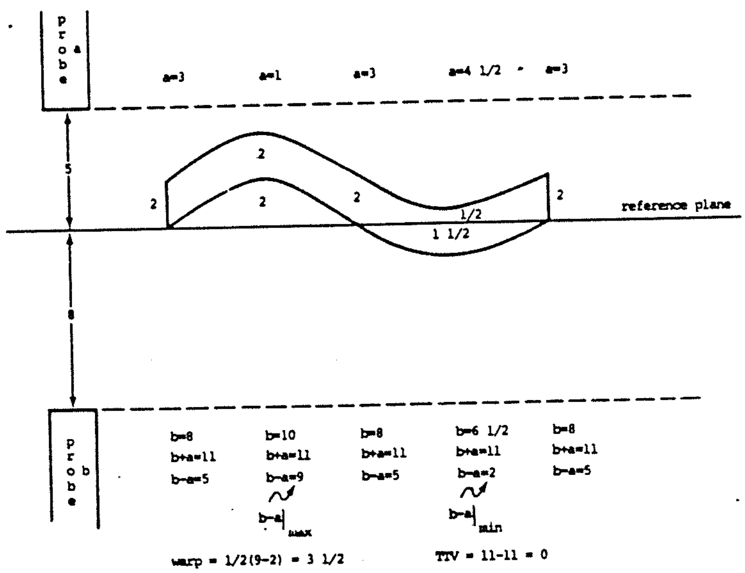

Figure 2: ASTM warp

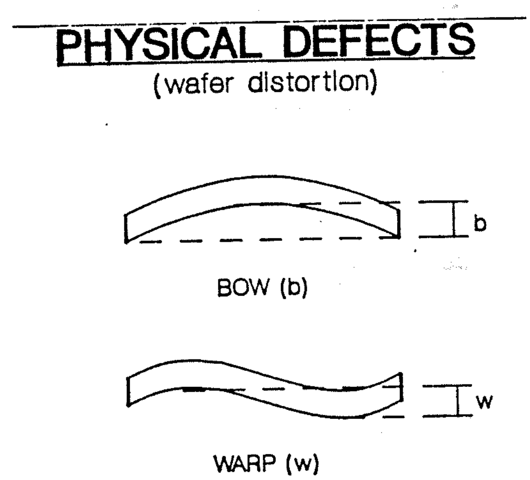

Figure 3: Bow and Warp for this test.

EXPERIMENT

Twenty-five Recticon, {100} wafers were scribed 1-25 then cleaned using the standard RCA procedure. Each wafer was measured before any heat cycles on a Tropel Autosort for bow and warp reference values. An experimental matrix, shown in Table 1, varied push/pull rates to determine the affects of heat stresses on the wafer. Each run had two test wafers placed between eight dummy wafers to better simulate an oxide growth process. Upon removal from the furnace, they were run through the Autosort to determine warp and bow again. Final results were the difference between the two measurements.

Table 1. Wafer number and push/pull rates for heat treat cycles.

Wafer #	Push rate	Pull rate
1,2	3	3
3,4	3	12
5,6	3	30
11,12	12	3
13,14	12	12 **
15,16	12	30
17,18	30	3
19,20	30	12
21,22	30	30

** This is the current R.I.T. practice for heat cycles.

After the bow and warp measurements were taken, the wafers were tested for slip using a Schimmel etch. The Schimmel etch was made by mixing one part .75 molar concentration of chromic acid and two parts hydrofluoric acid. To produce the .75 molar concentration of chromic acid, 75 grams of CrO_3 were added to 1 liter of DI water. The Schimmel etch is good for only a short period of time, therefore, the HF was not added until needed. Each wafer was immersed into a small amount of etch for 30 seconds. Slip lines were then noticeable under an optical microscope.

RESULTS/DISCUSSION

The Tropel Autosort gave contours of only the top surface. The method shown in Figure 3 for measuring bow and warp was used. The bow results are located in Table 2a. The data shows that bow follows no apparent pattern. Theory points to the fact that the stresses involved in heat cycles cause contortions to the wafer bulk. Bow is a measure of these stresses using height differences at the center and edges of the wafer. Bow becomes less relevant when warp is involved. As seen in Figure 2, the wafer showing warp has a bow value of zero, because the center of the wafer lies in the same plane as the edges. Thus, bow measurements seem irrelevant here.

Warp results are located in Table 2b. As the results show, the warp of the wafers increased drastically as the pull rate went from 3 to 12 inches per minute. The push rate didn't show a strong trend. Since the edges expand when heated, the affects of the push rate on warp are minimal compared to pull, Pulling causes the edges to contract while the center is still hot. One anomaly in the data shows that the warp measurement limit is somewhere around 1 um. This probably occurred because of the vacuum put on the wafer during measurement.

a) BOW (um)

PUSH RATE \ PULL RATE	3	12	30
3	0.6	0.0	0.4
12	0.2	0.3	0.1
30	0.0	0.3	0.4

b) WARP (um)

PUSH RATE \ PULL RATE	3	12	30
3	0.6	0.9	0.9
12	0.2	1.1	0.9
30	0.6	1.3	0.8

Table 2: Warp and Bow measurements

The third defect, slip, was affected by both the push and pull rates about equally. Tables 3a and 3b show the average and farthest distance into the wafer that the slip lines reach. The slip lines increased as both the push and pull rates increased. It can be safely said that slip is affected by stresses in both the expanding and constricting of the crystal lattice. In this test, slip only occurred on the edges and protruded in towards the center of the wafer.

a) Average slip distance from edge (cm)

PUSH RATE \ PULL RATE	3	12	30
3	0.0	0.4	0.4
12	0.3	0.5	0.6
30	0.3	0.5	0.5

b) Maximum slip distance from edge (cm)

PUSH RATE \ PULL RATE	3	12	30
3	0.0	0.4	0.8
12	0.9	0.9	1.3
30	1.0	1.0	1.1

Table 3: Slip Results

One observation showed that large slip lines occur near the wafer flat. As it turned out, the slip lines coincided with the wafer scribe marks put on the back side to label the wafers. These did not show up directly after scribing, but appeared after the heat cycles. This raises the possibility of latent stresses that might cause slip during later processes.

CONCLUSIONS

A list of push/pull rates that should be used to control each of the defects studied is as follows:

Defect	Push Rate (in/min)	Pull Rate (in/min)
Bow	Follow warp results	----------------->
Warp	12	3
Slip	12	3

These values take into account process time as well as defect problems. The slowest possible rate should be used without affecting throughput. My recommendation for the R.I.T. process would be a push rate of 12 and a pull rate of 3 inches per minute.

Another change in the R.I.T. process would be to change the scribing method. The diamond scribing method used here causes slip lines to occur during future heating cycles. Two alternatives could be, laser scribing, not available here, or one tool that R.I.T. now has that uses photoresist to make an image which is transferred in the next process step. Currently, this tool is set up for 4" wafers only.

ACKNOWLEDGMENTS

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